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Yuni Nurwati
Department of Community Nutrition, Faculty of Human Ecology, Institut Pertanian Bogor University, nurwatiyuni@apps.ipb.ac.id

Hardinsyah Hardinsyah
Department of Community Nutrition, Faculty of Human Ecology, Institut Pertanian Bogor University, hardinsyah@apps.ipb.ac.id

Sri Anna Marliyati
Department of Community Nutrition, Faculty of Human Ecology, Institut Pertanian Bogor University, marliyati@apps.ipb.ac.id

Budi Iman Santoso
Department of Community Nutrition, Faculty of Human Ecology, Institut Pertanian Bogor University, budiis54@gmail.com

Dewi Anggraini
Study Program of Statistics, Faculty of Mathematics and Natural Sciences, University of Lambung Mangkurat, dewi.anggraini@ulm.ac.id

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Effects of Maternal Anthropometry on Infant Anthropometry: A Cross-sectional Study at Public Hospital X in Ternate, Indonesia

Yuni Nurwati[1], Hardinsyah[2*], Sri Anna Marliyanti[2], Budi Iman Santoso[3], Dewi Anggraini[4]

[1]Postgraduate in Nutrition Science, Department of Community Nutrition, Faculty of Human Ecology, Institut Pertanian Bogor University, Bogor, Indonesia, [2]Department of Community Nutrition, Faculty of Human Ecology, Institut Pertanian Bogor University, Bogor, Indonesia, [3]Department of Obstetrics and Gynecology, Faculty of Medicine, University of Indonesia, Depok, Indonesia, [4]Study Program of Statistics, Faculty of Mathematics and Natural Sciences, University of Lambung Mangkurat, Banjarbaru, Indonesia

Abstract

Infant anthropometry is an indicator of neonatal survival. This study aimed to determine the effects of maternal anthropometry on estimating infant anthropometry. This cross-sectional study on 173 pregnant women at Public Hospital X in Ternate, Indonesia, was conducted from August 2018 to March 2023. The eligible criteria were pregnant women aged ≥18 years, single pregnancy, and antenatal care (ANC) visits to the same hospital. The variables used included maternal anthropometric measurements (body weight, body height, third-trimester weight (TTW)), gestational weight gain (GWG), education, age, ANC visits, and gestational age at delivery (GAD). A logistic regression model was employed to estimate significant variables related to infant anthropometric measurements (birth weight, birth length, and head circumference). The results showed that TTW, GWG, ANC, and GAD had significantly affected birth weight. Body weight, height, and TTW also significantly affected birth length. In addition, only GAD significantly affected the head circumference. In multivariate analysis, TTW and GWG significantly affected birth weight. Furthermore, only body height and GAD affected the birth length. Maternal anthropometrics become important indicators for estimating birth weight and birth length.

Keywords: birth length, birth weight, head circumference, logistic regression, maternal anthropometry

Introduction

Fulfillment of nutrition should meet nutritional needs, especially for vulnerable groups, including pregnant women. During pregnancy, pregnant women should ensure their energy and nutrient intake are sufficient to support fetal growth and development, in which according to the 2019 Indonesian Dietary Recommendation, they should add 180 to 300 kcal of energy.[1] By ensuring adequate nutrition meets nutritional needs, pregnant women will achieve normal gestational weight gain (GWG), an indicator of nutritional fulfillment during pregnancy.[2]

Infant health could be determined by examining infant anthropometric measurements, such as birth weight, birth length, and head circumference, representing a significant predictor of child survival, growth patterns, long-term health, and psychosocial development.[3] It is also very helpful in classifying an individual as having subnormal, normal, or excessive uterine growth.[3] Both subnormal and excessive intrauterine growth have been associated with a high risk of neonatal morbidity and mortality, as well as chronic diseases later in life.[3] An outcome of intrauterine growth restriction is low birth weight (LBW).[3] In addition, low and middle-income countries, including Indonesia, still have high rates of LBW, stunting at birth, and small for gestational age.[4]

LBW is the most common cause of infant death in Indonesia by 2021, while other causes are asphyxia, congenital abnormalities, infection, COVID-19, neonatal tetanus, and so forth.[5] The infant mortality rate (IMR) trend shows a decrease of 25% from 32 to 24 per 1,000 live births based on data from the 2017 Indonesian Demographic and Health Survey.[6] While, the National Medium-Term Development Plan target is to attain an IMR of 16 per 1,000 live births by 2024.[7] To achieve the target, the LBW incidence should be reduced.

Maternal nutritional status is the most frequently identified risk factor for subnormal fetal growth in developing countries.[3] Maternal anthropometric measurements, including body weight, body height, body mass index (BMI), mid-upper arm circumference, third-trimester weight (TTW), and GWG, are useful for assessing pregnancy outcomes.[3,8-9]

Correspondence*: *Hardinsyah, Department of Community Nutrition, Faculty of Human Ecology, Institut Pertanian Bogor University, Bogor 16680, Indonesia, E-mail: hardinsyah@apps.ipb.ac.id, Phone: +62 812-9192-259*

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Despite the fact that all of these maternal anthropometric measurements are routinely recorded during antenatal care (ANC) visits, such a crucial public health tool is frequently underused to ensure optimal pregnancy outcomes, particularly in rural areas where advanced technology is not accessible.[8]

Both early and late detections of pregnant women at risk of poor pregnancy outcomes are crucial. Early detection is essential since several interventions, such as energy and protein supplementation, have been shown to improve pregnancy outcomes.[3] While, late detection, in which most of the fetal organs have already developed, could still assist decision-making regarding prepartum referral to an appropriate facility for delivery and neonatal care.[3]

The Indonesian Government has implemented several programs to reduce the LBW incidence, such as integrated ANC, providing supplementary food to pregnant women with chronic energy deficiency, and detecting pregnant women at risk of giving birth to LBW infants by collaborating with primary health care.[10-11] However, the government still faces barriers while making efforts to prevent LBW, one of which is internal factors in pregnant women, such as illnesses suffered during pregnancy and inadequate nutritional knowledge.[12]

Unfortunately, only several studies have examined an association between maternal anthropometry, especially GWG, and birth outcomes in lower-income countries.[11,13-16] Given that maternal anthropometric measurements have many implications on maternal and child weight, this cross-sectional study aimed to evaluate maternal anthropometric measurements (body weight, body height, GWG, TTW, and gestational age at delivery (GAD)) and maternal factor (ANC visit) to estimate infant anthropometric measurements, such as birth weight, birth length, and head circumference. The findings obtained would support the early detection of pregnant women at risk for potential prenatal or perinatal intervention. Furthermore, this study contributes to improving the quality of ANC and neonatal outcomes in Indonesia.

Method

This study was conducted at Public Hospital X in Ternate City, North Maluku Province, Indonesia. Secondary data from hospital medical records were collected and analyzed. Of 478 pregnant women receiving ANC services and giving birth at the hospital from 2018-2023, only 173 (36.2%) met the inclusion criteria after the cleaning process. Public Hospital X was selected as it is the only hospital with complete data for analysis (all the maternal and infant anthropometric data needed for this study was available in the hospital's medical record database).

Pregnancy data were sourced primarily from the hospital's medical record database and the Maternal and Child Health Booklet for pregnant women receiving ANC services and giving birth at the same hospital. This study's protocol was reviewed correctly and granted by the Ethics Committee of the Faculty of Medicine, Hasanuddin University. Permission was also obtained from the head of Public Hospital X. The Ethics Committee ruled out the need for informed consent for no direct intervention with patients.

Data collection used consecutive sampling techniques from August 2018 to March 2023. The inclusion criteria were pregnant women aged ≥18 years, single pregnancy, taking ANC visits, and giving birth at the same hospital. Pregnant women with comorbidities, such as preeclampsia, gestational diabetes, and bleeding, were excluded from the study. All the comorbidities' data were available in the medical records.

The independent variables were maternal anthropometric measurements (body weight, body height, TTW), education, age, ANC visit, GWG, and GAD. The dependent variables were infant anthropometric measurements (birth weight, birth length, and head circumference). The instrument for measuring birth weight used a baby scale. Measurements of body length and birth head circumference were carried out within 24 hours after birth using a non-stretchable measuring tape to an accuracy of 0.5 cm.

There are 478 pregnant women receiving ANC services and giving birth at Public Hospital X from August 2018 to March 2023. After pre-processing data, 173 (36.2%) of 478 women met the study criteria. Of these women, 15.02% delivered LBW babies, and the remaining 84.98% delivered babies with normal weight. This study excluded 305 (63.8%) pregnant women due to incomplete information on the required characteristics.

Maternal characteristics were summarized using frequency distribution. Percentage was used to describe the study population characteristics. Bivariate analysis using the Chi-square test was conducted to analyze a correlation between maternal factors and infant anthropometry. Statistical significance was set at the 95% confidence level (p-value < 0.05). By using a binary logistic regression analysis, an estimation model was developed using infant anthropometry as outcomes. Maternal body weight (≥46 kg), body height (≥150 cm), TTW (≥60 kg), GWG (kg), ANC visits, and GAD (weeks) were estimators added to the regression model.

Results

Maternal and infant characteristics are presented in Table 1. The infant anthropometric measurement was taken within 24 hours after delivery. Based on frequency distribution in Table 1, most pregnant women had a body weight of

Table 1. Maternal and Infant Characteristics Among 173 Mother-Infant Pairs

Variable	Category	n	%
Body weight (kg)	<46	51	29.5
	≥46	122	70.5
Body height (cm)	<150	19	11
	≥150	154	89
Pre-pregnancy body mass index (kg/m^2)	Underweight	37	21.4
	Normal	118	68.2
	Overweight	9	5.2
	Obese	9	5.2
Third-trimester weight (kg)	<60	84	48.6
	≥60	89	51.4
Gestational weight gain (kg)	Inadequate	46	26.6
	Adequate	108	63
	Excessive	19	11
Education	High school	82	47.4
	Higher education	91	52.6
Maternal age (years)	≤19	5	2.9
	20–24	44	25.4
	25–29	71	41
	30–35	49	28.3
	>35	4	2.3
Antenatal care visit (times)	<4	45	26
	≥4	128	74
Gestational age at delivery (weeks)	<37	15	8.7
	37–41	154	89
	>41	4	2.3
Infant characteristic			
Birth weight (gram)	<2,500	25	14.5
	≥2,500	148	85.5
Birth length (cm)	<48	55	31.8
	≥48	118	68.2
Head circumference (cm)	<33	19	11
	≥33	154	89

Table 2. Association of Gestational Weight Gain with Infant Anthropometric

Variable	Category	Infant Anthropometric					
		Birth Weight (g)		Birth Length (cm)		Head Circumference (cm)	
		<2,500	≥2,500	<48	≥48	<33	≥33
Gestasional weight gain	Insufficient	12 (26.7)	33 (73.3)	31(68.9)	14 (31.1)	6 (13)	40(87)
	Adequate	10 (9.2)	99 (90.8)	18 (16.5)	91 (83.5)	8 (7.4)	100 (92.6)
	Excessive	3 (15.8)	16 (84.2)	6 (31.6)	13 (68.4)	5 (26.3)	14 (73.7)
	p-value	0.019*		<0.001*		0.045*	

Note: *Statistical significance set at 5%

≥46 kg (70.5%) and a body height of ≥150 cm (89%). Almost 70% of pregnant women had normal weight. Above 50% of pregnant women had 60 kg of TTW and adequate GWG (62.4%) during pregnancy. Most pregnant women graduated from university and were at the age group of 25-29 years. Above two-thirds (74%) had attended at least four ANC visits during their pregnancy.

Most infants had a birth weight of ≥2,500 grams (85.5%) and a birth length of ≥48 cm (68.2%). Almost 90% of infants had a head circumference of ≥33 cm. As much as 89% of infants were delivered at 37-41 weeks of gestational age. The relationship of GWG with maternal and infant anthropometry is shown in Table 2. Almost 91% of pregnant women had delivered infants with ≥2,500 grams. In contrast, pregnant women with GWG below the Institute of Medicine (IOM) recommendation levels gradually were more likely to deliver LBW infants (26.7%) compared to those with adequate GWG (9.2%). Maternal GWG was also significantly related to birth length (p-value <0.001). Almost 70% of mothers with inadequate GWG had delivered infants with a birth length of <48 cm.

In addition, most mothers with adequate GWG had delivered infants with a birth length of ≥48 cm (83.5%). Table

Table 3. Association of Maternal Characteristics with Infant Anthropometry

Variable	Category	Birth Weight (g)			Birth Length (cm)			Head Circumference (cm)		
		<2,500	≥2,500	p-value	<48	≥48	p-value	<33	≥33	p-value
		n (%)	n (%)		n (%)	n (%)		n (%)	n (%)	
Body weight (kg)	<46	11 (21.6)	40 (78.4)	0.085	22 (43.1)	29 (56.9)	0.038*	8 (15.7)	43 (84.3)	0.201
	≥46	14 (11.5)	108 (88.5)		33 (27)	89 (73)		11 (9)	111 (91)	
Body height (cm)	<150	4 (21.1)	15 (78.9)	0.485	12 (63.2)	7 (36.8)	0.002*	3 (15.8)	16 (84.2)	0.478
	≥155	21 (13.6)	133 (86.4)		43 (27.9)	111 (72.1)		16 (10.4)	138 (89.6)	
Pre-pregnancy BMI (kg/m²)	Underweight, over-weight, and obese	6 (11.3)	47 (88.7)	0.425	16 (30.2)	37 (69.8)	0.737	4 (7.5)	49 (92.5)	0.329
	Normal	19 (16)	100 (84)		39 (32.8)	80 (67.2)		15 (12.6)	104 (87.4)	
Third-trimester weight (kg)	<60	18 (21.4)	66 (78.6)	0.011*	33 (39.3)	51 (60.7)	0.040*	10 (11.9)	74 (88.1)	0.706
	≥60	7 (7.9)	82 (92.1)		22 (24.7)	67 (75.3)		9 (47.4)	80 (89.9)	
Gestational weight gain (kg)					21 (38.2)	34 (61.8)	0.232			
	Inadequate or excessive	16 (29.1)	39 (70.9)	0.001*	34 (29.1)	83 (70.9)		8 (14.5)	47 (85.5)	0.316
	Adequate	9 (7.7)	108 (92.3)					11 (9.4)	106 (90.6)	
Education	High school	10 (12.2)	72 (87.8)	0.423	28 (34.1)	54 (65.9)	0.528	11 (13.4)	71 (86.6)	0.331
	Higher education	15 (16.5)	76 (83.5)		27 (29.7)	64 (70.3)		8 (8.8)	83 (91.2)	
Maternal age (years)	≤19 or >35	1 (12.5)	7 (87.5)	0.867	2 (25)	6 (75)	0.665	1 (12.5)	7 (87.5)	0.893
	20-35	24 (14.6)	140 (85.4)		53 (32.3)	111 (67.7)		18 (11)	146 (89)	
Antenatal care visit (times)	<4	13 (28.9)	32 (71.1)	0.001*	19 (42.2)	26 (57.8)	0.081	7 (15.6)	38 (84.4)	0.254
	≥4	12 (9.4)	116 (90.6)		36 (28.1)	92 (71.9)		12 (63.2)	116 (90.6)	
Gestational age at delivery (weeks)	<37	8 (44.4)	10 (55.6)	<0.001*	8 (44.4)	110 (55.6)	0.231	5 (27.8)	13 (72.2)	0.017*
	≥37	17 (11)	137 (89)		47 (30.5)	107 (69.5)		14 (73.7)	140 (90.9)	

Notes: BMI = Body Mass Index, *Statistical significance set at 5%

Table 4. Association of Maternal Anthropometric Measurements and Antenatal Care Visit with Infant Anthropometric Measurements

Variable	Birth Weight			Birth Length			Head Circumference		
	p-value	AOR	95% CI	p-value	AOR	95% CI	p-value	AOR	95% CI
Body weight (kg)	0.451	0.6	0.2–2.1	0.968	0.9	0.4–2.5	-	-	-
Body height (cm)	0.370	1.9	0.5–7.9	0.006*	4.4	1.5–12.5	-	-	-
Third-trimester weight (kg)	0.043*	3.6	1.0–12.1	0.226	1.7	0.7–4.1	-	-	-
Gestational weight gain (kg)	0.001*	5.4	2.0–14.3	0.192	1.6	0.8–3.4	-	-	-
ANC visits	0.135	2.2	0.8–6.4	0.858	1.1	0.5–2.5	-	-	-
Gestational age at delivery (weeks)	0.243	2.2	0.6–8.2	0.035*	3.4	1.1–10.7	0.183	2.4	0.7–8.5

Notes: AOR = Adjusted Odds Ratio, CI = Confidence Interval, ANC = Antenatal Care, *Statistical significance set at 5%

2 also shows that maternal GWG is significantly related to the infant's head circumference (p-value = 0.045). Mothers with inadequate GWG had more infants with a head circumference of <33 cm (13%).

The association for all maternal anthropometric measurements with infant anthropometrics is shown in Table 3. The TTW, GWG, ANC visits during pregnancy, and GAD were significantly associated with birth weight. A significant association was also detected between body weight, body height, and TTW with birth length. Additionally, there was also a significant relationship between GAD and head circumference.

The next analysis was multivariate logistic regression on the relation between maternal anthropometry and infant anthropometry. Independent variables in bivariate analysis with a p-value of <0.25 were included in the multivariate analysis. Based on the final results of binary logistic regression in Table 4, pregnant women with a TTW of ≥60 kg gave birth to significantly normal infants compared to pregnant women with a TTW of <60 kg.

This study found that pregnant women with adequate GWG gave birth to neonates with a mean birth weight of 2,500 grams (Table 4). The results of this study also revealed that taller pregnant women (body height ≥150 cm) gave birth to significantly higher birth-length infants than shorter pregnant women. In addition, pregnant women delivering their babies at 37-41 weeks of gestation were significantly associated with normal infant length (>48 cm) compared to those delivering a baby below 37 weeks. On the other hand, there was no correlation between maternal characteristics and the head circumference of infants.

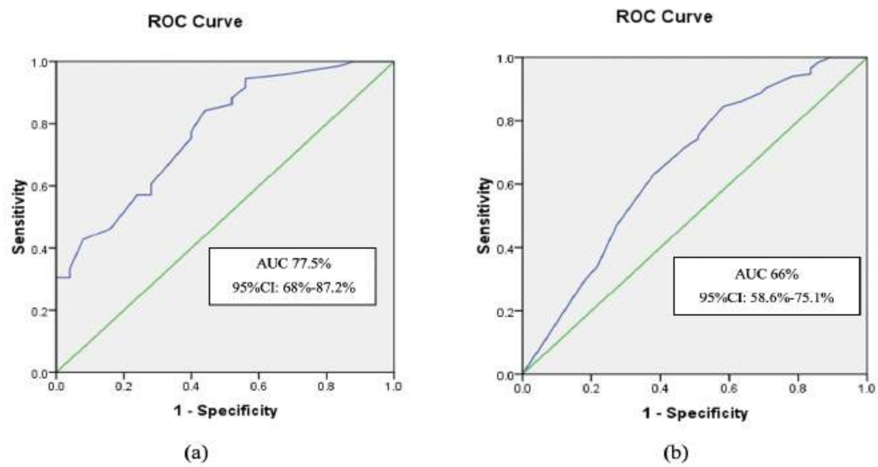

Figure 1. The Area Under the ROC Curve for Estimation Model (a) Birth Weight and (b) Birth Length

Discussion

This study found that both maternal anthropometry and ANC visits during pregnancy were associated with infant anthropometry, particularly birth weight and birth length. The association of maternal TTW of ≥60 kg and higher birth weight was similar to the previous studies.[8-9] In rural areas, most pregnant women usually visit their ANC during the third trimester. Therefore, early third-trimester weight could be an indicator of birth weight of 59.8 kg to 60.5 kg.

The optimal combination of maternal anthropometry to estimate weight was TTW and GWG. The combination of TTW and GWG to estimate birth weight resulted in an area under the ROC curve (AUC) of 77.5% (Figure 1a), which was moderate accuracy according to diagnostic accuracy classification.[16] Inadequate or excessive GWG has an impact on the mother and fetus.

A study by Abide et al.[17] with a retrospective study design at Zeyneb Kamil's Maternity and Children's Diseases Education and Research Hospital from 2014-2017 showed that GWG below the IOM recommendation was related to membrane rupture, LBW infants, intrauterine growth restriction, and admission to the neonatal intensive care unit. In addition, excessive GWG increases the risk of macrosomia in infants. Several studies also indicated that GWG has a significant relationship with birth weight.[17-19]

Moreover, an excessive GWG is also related to higher BMI during childhood and adolescence.[20-22] This is because pre-pregnancy BMI and excessive weight gain increased adipocytes in the fetus.[21-23] The fetal overnutrition hypothesis stated that increased transfer of nutrients from the placenta to the fetus would affect development, fat deposition, and development of the hypothalamic-endocrine system of fetus, controlling hunger and energy metabolism.[24]

In contrast, inadequate weight gain was related to the LBW infants as the increased nutritional intake during pregnancy for both mother and fetus is inadequate; therefore, the fetus does not receive the maximum nutrient transfer as needed.[25] As a consequence, this affects the birth weight of fetus.[25]

This study showed that birth length was affected by maternal body height and GAD. This combination resulted in an AUC of 66% (Figure 1b), which was a weak classifier accuracy according to diagnostic accuracy classification.[16] Previous studies also showed that maternal body height was associated with birth length.[26-28] The relationship between maternal height and birth length has been explained by a mechanism in which maternal height sets a physical constraint in the intrauterine environment (shorter women may have a smaller uterine, restricting fetal growth) and a reflection of cumulative social and nutritional conditions throughout life is an indicator of the biological and environmental factors that impact the growth and development of offspring in the uterus.[29]

Furthermore, genetic polymorphisms affecting maternal height may also have an immediate functional impact on the pregnancy outcomes in the fetus.[29] A study by Qurani et al.[30] showed that maternal height is the only factor significantly associated with the incidence of stunting. There is a cycle of intergenerational malnutrition in the future; stunted children will become short mothers who will also give birth to stunted children.[31]

Body height is affected by various factors such as genetics, nutrition, and infectious diseases.[32] If both mother and father are short in height because of certain infectious diseases or inadequate nutrients during adolescence, the stunting risk of their offspring could be avoided. It could be explained that the risk of stunting could be avoided if the children get adequate nutrition and are not exposed to other risk factors.[32] The risk of growth faltering is greater in the fetus with the suffering of falter in uterus.[32]

Maternal height and age at delivery (weeks) were the combination affecting the birth length. A study by Derraik et al.[33] showed that decreased gestational age was linked to a shorter final height, and this correlation was especially marked in women who were born very preterm. Pregnant women delivering their babies before 37 weeks of gestational age were at greater risk of delivering an infant with a birth length of <48 cm.

This study found that nutrition was important for the process of growth and bone formation from the beginning of fetal life until the end of pregnancy. A systematic review conducted by Nurwati et al.[34] showed that several maternal risk factors contributing to LBW were maternal nutritional status and education. Krismanita et al.[35] indicated that maternal height was the dominant factor in the prevalence of a dual form of malnutrition. Therefore, it is recommended to improve nutrition in adolescence, especially for girls in their role as future mothers, for example, through intervention by nutrition education, micronutrient supplementation, and treatment of comorbidities.

The maternal nutritional status will determine the nutrient reserves required for fetal organogenesis, including bone development.[36] Mothers who are unable to supply the protein needs of fetuses will alter chondrocyte cell proliferation in the proliferation zone so that the thickness of proliferation zone is reduced.[36] Furthermore, if pregnant women are unable to supply the fetal calcium and zinc needs, the development of hydroxy acid crystals in maturation zone decreases, eventually limiting the process of mineralization and bone calcification in the cartilage zone.[36] Moreover, inadequate intake of calcium, phosphorous, and magnesium in the mineralized zone will cause the thickness of the mineralized zone to decrease.[37] Overall, inadequate nutrients cause the thickness of the epiphyseal plate thickness.[37] The lack of epiphyseal plate thickness will reduce the fetal length and reduce the potential fetal length after birth.[37]

In the multivariate analysis estimation model, there is an easily accessible estimate variable to be used in Integrated Health Care (IHC). The maternal variables significantly affecting the birth weight were TTW and GWG, with an AUC of 77.5% (95%CI = 68-87.2%). While, variables significantly affecting the birth length were maternal body height and gestational age at delivery, with an AUC of 66% (95% CI = 58.6-75.1%). The strength of this study is that all the estimator variables could be easily found from physical measurements. Therefore, it could be simply applied at the IHC or in rural areas where advanced technology is unavailable. This study's limitation is that the samples were taken from only one hospital.

Conclusion

Pregnancy outcomes can be determined through maternal anthropometric factors: body weight, body height, TTW, GWG, and GAD. All of these factors can be gained during ANC visits. Variables such as lower body weight and shorter body height can be potential risk factors for LBW and shorter birth length. To improve pregnancy outcomes, a collaboration between health workers and pregnant women is important so that intervention can be given from early pregnancy. Further studies can continuously validate the estimation tool using new studies with more variables, preferably using a prospective study design.

Abbreviations

GWG: Gestational Weight Gain; LBW: Low Birth Weight; IMR: Infant Mortality Rate; BMI: Body Mass Index; TTW: Third-trimester Weight; ANC: antenatal Care; GAD: Gestational Age at Delivery; IOM: Institute of Medicine; AUC: Area Under the ROC Curve; IHC: Integrated Health Care.

Ethics Approval and Consent to Participate

This study was approved by the Ethical Committee of the Faculty of Medicine, Hasanuddin University, ref: 785/UN4.6.4.5.31/PP36/2022. Permission was also obtained from the head of the Public Hospital X.

Competing Interest

The authors declare that no significant competing financial, professional, or personal interests might have affected the performance or presentation of the work described in this manuscript.

Availability of Data and Materials

Data were obtained from the hospital medical record database and the Maternal and Child Health Booklet.

Authors' Contribution

YN, HH, and SAM considered the study, interpreted the results, and co-wrote the manuscript. YN, SAM, BIS, and DA collected the data, assisted with information interpretation, and co-wrote the manuscript. All the authors read and accepted the last manuscript.

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